Sternostoma
(arachnid: mite)

Overview

Arthropods are coelomate metameric invertebrate animals with a chitinous exoskeleton and jointed limbs. They undergo protostomial embryonic development and grow by cuticular moulting (ecdysis). Three main subphyla are recognized: Chelicerata, Crustacea and Hexapoda. Arachnids have chelicerate mouthparts, two tagmata (cephalothorax and abdomen), four pairs of legs and slit sensilla, but no antennae or wings. All species exhibit incomplete metamorphosis whereby eggs hatch larvae which moult to nymphs and then adults. Acarines comprise the ticks and mites which have sac-like bodies with inconspicuous segmentation and their mouthparts are confined to an anterior gnathosoma. Four major groups are recognized primarily on the location of their respiratory stigmata: ixodid ticks (Metastigmata), gamesid mites (Mesostigmata), trombidiform mites (Prostigmata) and sarcoptiform mites (Astigmata). Ectoparasitic mites inhabit the skin of mammals and birds, feeding on fluids and/or tissues. Most spend their entire lives on individual hosts, so horizontal transmission between hosts is primarily by physical contact. Gamesid mites have anterior legs with respiratory stigmata located between the second and fourth legs. Most species are predatory, but some are ectoparasitic on mammals, birds and insects. They usually have a large sclerotized dorsal shield and a series of smaller ventral shields. Rhinonyssid mites are found in the nasopharynx of wild and domestic birds. Infestations by *Sternostoma* spp. may cause respiratory problems in aviary birds.

Classification:

Domain:	Eukaryota (membrane-bound nucleus)
Supergroup:	Amorphea (unikonts with single flagellum, or nonflagellated amoebae)
Kingdom:	Metazoa (multicellular eukaryotes, heterotrophs, notably animals)
Group:	Protostomia (triploblastic, spiral cleavage)
Subgroup:	Ecdysozoa (cuticle moulted = ecdysis)
Phylum:	Arthropoda (chitinous exoskeleton, segmented body, jointed limbs, haemocoel)
Subphylum:	Chelicerata (chelicerate mouthparts, two tagmata, no antennae)
Class:	Arachnida (spiders & allies, four pairs of legs, slit sensilla, incomplete metamorphosis)
Subclass:	Acari (Acarina) (ticks and mites, segmentation inconspicuous, sac-like body, mouthparts on gnathosoma)
Superorder:	Parasitiformes (ticks and some mites, with posterior stigmata)
Order:	Mesostigmata (gamesid mites, legs grouped anteriorly, stigmata between second and fourth legs)
Suborder:	Dermanyssina (sclerotized shields, reduced setae, legs with claws)
Superfamily:	Dermanyssoidea (elongate edentate chelicerae, diverse life-styles)
Family:	Rhinonyssidae (parasites of nasopharynx of birds)
Genus:	*Sternostoma* (parasitic in nasal passages of birds)
Species:	various species cause respiratory problems in caged birds

Parasite biodiversity and host range: Most Metazoa are multicellular triploblastic animals with differentiated tissues, many being bilaterally symmetrical with a body cavity. Most invertebrate animals are protostomes as their embryonic development involves spiral determinate cleavage. Those that moult their external cuticles during their life-cycles (process known as ecdysis) are grouped together in the unique clade Ecdysozoa, including the nematodes (roundworms), onychophorans (velvet worms), tardigrades (water bears) and arthropods (myriapods, chelicerates, crustaceans and hexapods). Arthropods have small segmented bodies encased in chitinous exoskeletons with articulated limbs. Most species are free-living in terrestrial and aquatic habitats, although a small range are ectoparasitic on other animals, some feeding on the blood or skin of vertebrates. Five subphyla are recognized: Chelicerata, Crustacea, Hexapoda, Myriapoda and Trilobita. The chelicerates typically have appendages (chelicerae) in the form of pincers or fangs anterior to the mouthparts, 2 body parts (cephalothorax and abdomen), but no antennae or wings. Three classes are recognized: Arachnida (spiders and allies), Merostomata (horseshoe crabs) and Pycnogonida (sea spiders). Arachnids have 8 legs, slit sensilla and life-cycles involving incomplete metamorphosis whereby larvae and nymphs resemble adults. They are classified in 4 orders: Acari (acarines), Araneae (spiders), Opiliones (harvestmen) and Scorpiones (scorpions). The Acari comprises the ticks and mites which have saccular bodies and mouthparts confined to an anterior gnathosoma. Four major groups are recognized primarily on the location of their respiratory stigmata (called spiracles in insects): ixodid ticks (posterior Metastigmata), gamesid mites (middle Mesostigmata), trombidiform mites (anterior Prostigmata) and sarcoptiform mites (without stigmata = Astigmata).

Major parasitic families	Biodiversity	Hosts	Parasitic stages	Pathogenesis	Disease transmission
Superorder: Parasitiformes (ticks and some mites, with posterior stigmata)					
Order: Ixodida [Metastigmata] (ticks, macroscopic, stigmata posterior to legs) [3 families]					
Argasidae (soft ticks)	5 genera, 193 species	birds, mammals	larvae, nymphs, adults	blood-sucking	viral, bacterial
Ixodidae (hard ticks)	14 genera, 705 species	birds, mammals	larvae, nymphs, adults	blood-sucking, paralysis	viral, bacterial, protozoal
Order: Mesostigmata [Gamasida] (gamesid mites, stigmata between 2nd & 4th legs) [100 families, 662 genera, 5,360 species]					
Macronyssidae (sucking mites)	26 genera, 127 species	birds, reptiles, mammals	nymphs, adults	blood-sucking	bacterial
Dermanyssidae (sucking mites)	5 genera, 37 species	birds, mammals	nymphs, adults	blood-sucking	viral, bacterial
Halarachnidae (lung/ear mites)	7 genera, 10 species	mammals	nymphs, adults	mucosal erosion	-
Raillietiidae (ear mites)	1 genus, 7 species	mammals	nymphs, adults	ear wax	-
Rhinonyssidae (nasal mites)	30 genera, 160 species	birds	nymphs, adults	inflammation	-
Varroidae (bee mites)	1 genus, 5 species	bees	nymphs, adults	haemolymph-feeding	viral
Superorder: Acariformes (diverse group of mites, without posterior stigmata) [351 families, 32,000 species]					
Order: Prostigmata [Trombidiformes, Actinedida] (sucking mites, stigmata on gnathosoma) [121 families, 17,000 species]					
Demodecidae (follicle mites)	7 genera, 65 species	mammals	larvae, nymphs, adults	inflammation	-
Cheyletidae (fur mites)	80 genera, 500 species	mammals (dogs, cats, rabbits), birds	larvae, nymphs, adults	pruritus	-
Myobiidae (fur mites)	46 genera, 185 species	mammals (rodents, bats, marsupials)	larvae, nymphs, adults	mange	-
Psorergatidae (itch mites)	3 genera, 77 species	mammals (rodents, artiodactyls)	larvae, nymphs, adults	mange	-
Trombiculidae (chigger mites)	71 genera, 3,000 species	mammals, birds	larvae	skin-feeding	bacterial
Order: Astigmata [Sarcoptiformes, Acaridida] (fur/feather/itch/dust mites, lacking stigmata) [230 families, 15,000 species]					
Sarcoptidae (itch mites)	3 genera, 42 spp./ssp.	mammals	larvae, nymphs, adults	scabies, mange	-
Psoroptidae (scab mites)	20 genera, species	mammals (carnivores, ungulates)	larvae, nymphs, adults	mange	-
Listrophoridae (fur mites)	20 genera, 170 species	mammals (esp. rodents)	larvae, nymphs, adults	mange	-
Myocoptidae (fur mites)	10 genera, 70 species	mammals (esp. rodents)	larvae, nymphs, adults	myocoptic mange	-
Cytoditidae (airsac/nasal mites)	2 genera, 12 species	birds	larvae, nymphs, adults	respiratory signs	-
Knemidokoptidae (burrowing mites)	7 genera, 16 species	birds	larvae, nymphs, adults	scaly face, scaly leg	-
Laminosioptidae (quill/skin mites)	8 genera, 25 species	birds	larvae, nymphs, adults	flesh/skin lesions	-

The superorder Parasitiformes comprises acarines with posterior respiratory stigmata and includes two major orders: the ixodid ticks (order Metastigmata) with stigmata located posterior to the legs; and the gamesid mites (order Mesostigmata) where they are located between the legs, sometimes associated with sinuous processes (peritremes). Mesostigmatid mites are further characterized by possessing unbarbed hypostomes, and long legs with free coxae (not fused to the body wall). The order Mesostigmata contains thousands of mites, with over 5,000 species recognized in 660 genera and 100 families. Nine suborders are recognized (Antennophoria, Arctacarina, Cercomegistina, Dermanyssina, Epicriina, Microgyniina, Parasitina, Sejina, and Uropodina). The suborder Dermanyssina contains robust mites with distinct sclerotized dorsal and ventral shields, reduced setae, palps with 2-tined apoteles, and legs with tarsal claws. Five superfamilies are recognized (Ascoidea, Dermanyssoidea, Eviphidoidea, Rhodacaroidea, and Veigaioidea). The superfamily Dermanyssoidea contains a diverse array of mites including free-living predators, nidicoles in the nests of vertebrates and insects, obligate and facultative ectoparasites of vertebrates and arthropods, and even respiratory and auditory endoparasites of mammals, birds, and some reptiles. The mites have elongated chelicerae (long first or

second segment) with small edentate digits and concave interior margins (functioning as a tube when in opposition). A total of 11 families are recognized (Dermanyssidae, Haemogamasidae, Halarachnidae, Hirstionyssidae, Ixodorhynchidae, Laelapidae, Macronyssidae, Raillietiidae, Rhinonyssidae, Spinturnicidae, and Varroidae), many of them exclusively parasitic.

The family Rhinonyssidae contains obligate endoparasites living their entire lives within the respiratory systems of birds. Some 30 genera have been described (*Agapornyssus*, *Astridiella*, *Charadrinyssus*, *Falconyssus*, *Hapalognatha*, *Larinyssus*, *Locustellonyssus*, *Mesonyssoides*, *Mesonyssus*, *Neonyssus*, *Neotyranninyssus*, *Passeronyssus*, *Pipronyssus*, *Psittonyssus*, *Ptilonyssoides*, *Ptilonyssus*, *Rallinyssus*, *Rhinoecius*, *Rhinonyssus*, *Rhinosterna*, *Ruandanyssus*, *Sternoecius*, *Sternonyssus*, *Sternostoma*, *Sternostomoides*, *Sternostomum*, *Tinaminyssus*, *Trochilonyssus*, *Tyranninyssus*, *Zumptnyssus*) and differentiated primarily by the morphology of stigmata (presence or absence of peritremes), gnathosoma (shape of mouthparts, presence of 1 or 2 fingers of chelicerae,) sclerotization of idiosoma (shape and size of shields) and chaetotaxy (patterns of setae). Rhinonyssid protonymphs and deutonymphs are similar in appearance; they do not have well-developed dorsal shields, the tritosternum is absent in all developmental stages, and the anus is located ventrally or terminally. The genus *Sternostoma* comprises mites with dorsolateral stigmata (lacking peritremes), ventral gnathosoma (only the most distal part extending beyond the idiosoma), 2 dorsal shields, and 3 ventral shields (the genital shield being rudimentary). The genus is specious and contains over 70 species parasitizing the nasal cavities, trachea and air sacs of a wide range of birds (belonging to over 10 avian orders).

***Sternostoma* species**	**Hosts**	**Clinical signs**	**Distribution**
S. alexfaini	Passeriformes: laniid (great grey shrike, red-backed shrike)		Europe
S. alexmironi	Passeriformes: muscicapid (northern wheatear)		Russia
S. artami	Passeriformes: artamid (white-breasted wood swallow)		Papua New Guinea
S. augei	Strigiformes: strigid (burrowing owl)		South America
S. batis	Passeriformes: furnariid (Spix's woodcreeper)		South America
S. boydi	Charadriiformes: scolopacid (sanderling, greater yellowlegs), larid (herring gull, ring-billed gull, common tern)		North America
S. bruxellarum (syn. *Ptilonyssus elbeli*)	Passeriformes: sturnid (common starling, black-collared starling, rosy starling, common mynah)		Eurasia, North America
S. castroae	Passeriformes: motacillid (yellow-throated longclaw)		Africa
S. chakarovae	Passeriformes: muscicapid (northern wheatear)		Russia
S. christinae	Passeriformes: phylloscopid (common chiffchaff)		Europe
S. cisticolae	Passeriformes: cisticolid (rattling cisticola)		Africa
S. clementei	Passeriformes: tyrannid (blue-billed black tyrannt)		South America
S. colii	Passeriformes: coliid (speckled mousebird)		Africa
S. constricta	Passeriformes: paradisaeid (Raggiana bird-of-paradise)		Papua New Guinea
S. cooremani	Coraciiformes: meropid (European bee-eater), alcedinid (collared kingfisher)		Africa, Malaysia
S. cordiscutata	Cuculiformes: cuculid (white-eared bronze cuckoo)		Papua New Guinea
S. crotophagae	Cuculiformes: cuculid (groove-billed ani)		North America
S. cryptorhynchum	Passeriformes: passerid (house sparrow)		Europe
S. cuculorum (syn. *S. zosteropus*)	Cuculiformes: cuculid (red-chested cuckoo, Diederik cuckoo, Levaillant's cuckoo); Passeriformes: laniid (magpie shrike), zosteropid (silvereye)		Africa, Australia
S. darlingi	Passeriformes: tyrannid (northern tufted flycatcher)		Central America
S. delianovae	Passeriformes: turdid (fieldfare)		Russia
S. dumetellae	Passeriformes: mimid (gray catbird)		North America
S. dureni	Passeriformes: turdid (common blackbird, olive thrush, mountain thrush), leiothrichid (arrow-marked babbler, black-faced babbler)		Africa, Australia, Russia
S. epistomata (syn. *S. chlidoniadis*)	Charadriiformes: larid (black tern, whiskered tern)		Russia
S. eurocephali	Passeriformes: laniid (southern white-crowned shrike)		Africa
S. ficedulae	Passeriformes: muscicapid (collared flycatcher)		Europe
S. francolini	Galliformes: phasianid (Coqui francolin)		Africa
S. fulicae	Gruiformes: rallid (Eurasian coot)		Europe
S. furmani	Galliformes: phasianid (bar-backed partridge)		Malaysia
S. gallowayi	Passeriformes: alaudid (horned lark)		North America
S. giganteum	Passeriformes: platysteirid (chinspot batis)		Africa
S. gliciphilae	Passeriformes: meliphagid (brown honeyeater)		Australia

S. guevarai	Galliformes: phasianid (red-legged partridge)		Europe
S. hedonophilum	Passeriformes: tyrannid (cinnamon-crested spadebill)		South America
S. hirundinis	Passeriformes: hirundinid (white-headed saw-wing, pearl-breasted swallow, barn swallow, purple martin), cisticolid (lazy cisticola)		Africa, North America
S. hirundo	Passeriformes: hirundinid (barn swallow, pearl-breasted swallow, Ethiopian swallow)		Africa
S. hutsoni	Passeriformes: turdid (Swainson's thrush)		North America
S. hylandi	Piciformes: picid (downy woodpecker)		North America
S. inflatum	Passeriformes: leiothrichid (arrow-marked babbler, black-faced babbler)		Africa
S. isabelae	Passeriformes: alaudid (red-capped lark)		Europe
S. kelloggi	Passeriformes: mimid (gray catbird, brown thrasher)		North America
S. lagonostictae	Passeriformes: estrildid (African firefinch)		Africa
S. laniorum	Passeriformes: laniid (red-backed shrike, great grey shrike, southern fiscal), platysteirid (chinspot batis)		Africa
S. longosetosa	Passeriformes: tyrannid (eastern kingbird)		North America
S. loxiae	Passeriformes: fringillid (red crossbill)		Europe
S. marchae	Passeriformes: fringillid (canary)		Russia
S. mortelmansi	Apodiformes: trochilid (hummingbird)		South America
S. motacilli	Passeriformes: motacillid (water pipit)		North America
S. nectarinia	Passeriformes: nectariniid (copper sunbird, scarlet-crested sunbird, purple-breasted sunbird)		Africa
S. neosittae	Passeriformes: neosittid (varied sitella)		Australia
S. opistaspis	Passeriformes: artamid (hooded butcherbird)		Papua New Guinea
S. paddae	Passeriformes: estrildid (Java sparrow)		Asia
S. pastor	Passeriformes: sturnid (rosy starling)		Europe (zoo)
S. pencei	Passeriformes: tyrannid (yellowish flycatcher)		Central America
S. pirangae	Passeriformes: cardinalid (summer tanager)		North America
S, porteri	Piciformes: picid (northern flicker, downy woodpecker)		North America
S. quiscali	Passeriformes: icterid (Carib grackle)		Central America
S. sayornis	Passeriformes: tyrannid (black phoebe)		North America
S. schiffornis	Passeriformes: tityrid (brown-winged schiffornis)		South America
S. setifer	Passeriformes: tyrannid (least flycatcher)		North America
S. sialiphilus	Passeriformes: turdid (eastern bluebird)		North America
S. sinense	Passeriformes: leiothrichid (red-billed leiothrix)		Europe (zoo)
S. spatulatum	Passeriformes: turdid (olive-backed thrush, hermit thrush)		North America
S. sternahirundo	Charadriiformes: larid (common tern)		Russia
S. straeleni	Passeriformes: sturnid (violet-backed starling)		Africa
S. strandtmanni	Passeriformes: icterid (tricolored blackbird, red-winged blackbird, brown-headed cowbird, common grackle, boat-tailed grackle)		North America, Europe
S. strigitis	Strigiformes: strigid (long-eared owl)		Russia
S. sturnicola	Passeriformes: sturnid (Ruppell's starling), buphagid (yellow-billed oxpecker)		Africa
S. tangarae	Passeriformes: thraupid (turqoise tanager, summer tanager)		Americas
S. technaui (syn. *S. borceanum, turdi*)	Passeriformes: turdid (American robin, true thrush, olive thrush, song thrush, Abyssinian thrush, cocoa thrush, red-throated thrush, spectacled thrush, common blackbird, fieldfare, ring ouzel), cinclid (white-throated dipper)		Africa, Eurasia, North America
S. thienponti	Passeriformes: dicrurid (fork-tailed drongo)		Africa
S. tracheacolum (syn. *S. meddai*) (air-sac mite, canary mite)	Passeriformes: fringillid (canary, finch, goldfinch), emberizid (bunting), hirundinid (swallow, tree swallow), icterid (brown-headed cowbird, oriole), motacillid (wagtail), parulid (water thrush), passerid (sparrow), sturnid (starling, meadowlark), sylviid (warbler), thraupid (tanager), turdid (blackbird), tyrannid (great crested flycatcher); Psittaciformes: psittacid (parrot), psittaculid (parakeet)	illness, death	Africa, North America

S. tyrannus	Passeriformes: tyrannid (olive-sided flycatcher)		North America
S. ubedai	Passeriformes: sylviid (Sardinian warbler)		Europe
S. ziegleri	Cuculiformes: cuculid (brush cuckoo)		Papua New Guinea
S. zini	Cuculiformes: cuculid (common cuckoo)		Russia

Parasite morphology: *Sternostoma* spp. form 4 different types of morphological stages during their development: eggs; larvae; nymphs; and adults. Eggs observed *in utero* were oval-round measuring from 0.10-0.35 mm long and surrounded by a thin smooth shell. They embryonated *in utero* to contain fully-formed larvae. Depending on the mite species, the eggs either hatched rapidly after oviposition (ovoviviparity) or they hatched *in utero* so females birthed live larvae (viviparity). Free larvae were ovate measuring 0.2-0.4 mm long and were lightly sclerotized and colorless (almost transparent). They possessed a small but well-developed gnathosoma (head or capitulum) with rudimentary mouthparts and short palps. The larger idiosoma (body) lacked sclerotized plates (shields) in most species, although a few displayed vague anal and podosomal shields (e.g. *S. technaui*). All larvae characteristically had 3 pairs of jointed legs (albeit weakly-developed with reduced claws) and lacked respiratory openings (stigmata). Nymphs were ovate to ellipsoidal measuring 0.3-0.5 mm long and were light brown to white (almost transparent), but became reddish-brown when gorged. They characteristically had 4 pairs of jointed legs and a pair of lateral stigmata with short peritremes. All nymphs had a ventral or terminal anus but lacked a tritosternum. They possessed a growing number of setae, but not quite as many as adults. There were 2 nymphal instars (protonymphs and deutonymphs) which were similar in appearance, except that protonymphs were slightly smaller and had well-developed mouthparts with sclerotized chelicerae and sharp movable digits (while deutonymphs had poorly sclerotized chelicerae that ended bluntly). The idiosoma of protonymphs usually lacked sclerotized shields, although a few species had a vague opisthosomal dorsal shield. The idiosoma of deutonymphs had a small anal shield and while most species lacked other shields, several had precursors of shields present in adults. In these cases deutonymphs could be differentiated from adults by the absence of genital apparatus. Adult mites had thick oval-ellipsoidal bodies that were cream-yellow in colour and ranged in dimensions from 0.25-0.80 x 0.15-0.40 mm. Females were larger in size than males (0.4-0.8 x 0.2-0.4 mm v. 0.25-0.35 x0.15-0.23 mm) and their genital openings (gonopores) were located posterior to the sternal plate (rather than anterior like males). Adults had a small gnathosoma, the bulk of which was ventral and only the most distal portions extended beyond the idiosoma. The gnathosoma contained the mouthparts (paired chelicerae and central hypostome) flanked by sensory palps. The palps were segmented with distal segments curved inwards and bearing a small terminal claw (apotele) while the basal segments were fused to form a basis capitulum. The chelicerae had 3 segments with the basal segments having swollen bases and the terminal segments bearing claw-like chelae (pincers) with a small fixed digit and a larger movable digit (modified in males for sperm transfer). The mouth consisted of a dorsal rostrum, a ventral buccal cone and a central unbarbed hypostome. The alimentary tract comprised the mouth (with long paired salivary glands), foregut (with tubular oesophagus and pharynx), midgut (with saccular ventriculus with gastric caeca) and the hindgut (short intestines with excretory Malpighian tubules) leading to the rectum and ventral or terminal anus. The idiosoma possessed numerous short setae and had distinctive sclerotized shields, 2 dorsal (podosomal and opisthosomal) and 3 ventral (sternal, genitoventral, and anal), most of them patterned by fine lines. The podosomal shield was pentagonal-triangular in shape with rounded edges, while the opisthosomal shield was smaller and elongate. The sternal shield was rectangular while the genitoventral shield was similar in size but oval. The anal shield was small and rounded, and females had a rudimentary genital (epigynal) plate. The anteroventral idiosoma lacked a tritosternum but was the point of attachment for 4 pairs of stout legs. Each leg had 6 segments (coxa, trochanter, femur, genu, tibia and tarsus) and ended in a short stalked pretarsus bearing an expanded pretarsal apparatus (ambulacrum) with large paired curved claws and an empodium (pad-like pulvillus). The forelegs had poorly-developed elongate claws, while the remaining legs had well-developed larger claws. Adults had a pair of lateral stigmata located between coxae II and IV (like other mesostigmatid mites) but most species lacked peritremes. Males had paired testes with tubular vas deferens leading to the ejaculatory duct and sheathed aedeagus (penis). Females had 2 ovaries with ovarioles) joined by tubular oviducts to the uterus (with accessory shell-glands) and a bipartite vagina (with a bursa copulatrix for sperm reception, and saccular spermathecae for sperm storage).

Site of infection: Rhinonyssid nasal mites are permanent endoparasites that inhabit the respiratory tracts of birds. Most species live in the upper respiratory tract in the nasal cavity and buccal cavity (primarily in the region between the larynx and the palatal folds). However, some species may occupy the trachea, syrinx, primary bronchi, air passages of the lungs and all major air sacs (including the cervical, interclavicular, anterior and posterior thoracic, and abdominal air sacs). On rare occasions, mites have been found in the oesophagus, the proximal pneumatized humerus, and in the body cavity on the mesentery near the liver, kidneys, intestines and ovaries/testes. Around 75 mite species have been described from birds belonging to 35 passerine families and 13 nonpasserine families in 9 orders (including shorebirds, kingfishers, cuckoos, woodpeckers, hummingbirds, fowl, parrots, owls). While all stages occur within the same host, gravid females are more often found lower in the respiratory tree than non-gravid non-gorged females which occur mainly in the upper respiratory passages.

Pathogenesis: Many infestations by nasal mites are light and remain asymptomatic, but heavier infestations may cause respiratory distress which can prove fatal (disease called rhinonyssidosis). Protonymphs and adult mites use their mouthparts to lacerate respiratory epithelia to feed on host blood and lymph, in so doing causing traumatic lesions, irritation, catarrhal inflammation, petechial haemorrhages and excessive mucus production leading to congestion and even pneumonia. Infested birds exhibit a range of clinical signs, including throat clearing, sneezing, coughing, audible dyspnoea (wheezing with squeaking, gurgling or clicking),

open-mouthed breathing, excessive salivation (ptyalism), wet nostrils, bill wiping, head shaking, tail bobbing, and aphonia. Inflammation of the respiratory tree may range from the trachea (tracheitis) to the air-sacs (aerocystitis). Birds become less active and weak, exhibit exercise intolerance and fly less often for shorter periods, lose weight to the point of emaciation, and appear fluffy with deteriorating feather quality. Affected birds may also develop secondary pyogenic infections. Mite infestations may persist for months and mortality rates can be high with deaths due to occlusion of the respiratory passages and suffocation. Disease is more severe in captive birds than wild birds, and in young birds than in adults. Clinical signs are exacerbated by handling, exercise, and other stresses. Mite populations in surviving individual birds decline over 1-2 years but may persist at low numbers for extended periods. The prevalence and intensity of infestations was not correlated to host biological events such as breeding, nesting, fledgling or seasonal migration. There has been much speculation as to whether *Sternostoma* mites act a vectors or reservoirs for infectious microbial diseases (such as bacterial Q fever and Lyme disease or viral West Nile fever and avian influenza), but their role in the maintenance or transmission of these pathogens remains to be determined.

Developmental cycle and mode of transmission: Nasal mites undergo incomplete (hemimetabolous) metamorphosis whereby eggs hatch larvae which moult to nymphs and then to adults. The whole life cycle may be completed in the respiratory system of the host, but only protonymphs and adults are blood-feeding stages (whereas larvae and deutonymphs have rudimentary mouthparts and are considered to be non-feeding stages). Depending on the species, gravid female mites are either larviparous or ovoviviparous and give birth to live larvae or larvated eggs that rapidly hatch. Studies on *S. tracheacolum* found that eggs hatched within 20 hours of oviposition on respiratory epithelia, while eggs of other species are rarely encountered. All species demonstrated rapid development to adults within 4-5 days. Larvae did not feed on blood and moulted to the first nymphal instar (protonymphs) in 1-2 days. The protonymphs did feed on blood and they moulted rapidly after bloodmeals to form the second nymphal instar (deutonymphs). Deutonymphs were not observed to feed and any blood found in their guts was attributed to the carry-over of undigested blood from the previous protonymph stages. Deutonymphs moulted rapidly to adult mites which then commenced to feed by apparently taking multiple small meals. The reproductive cycles of the few mite species that have been studied indicate that female mites may produce progeny with or without mating. Eggs that have been fertilized by sperm develop into diploid females, whereas unfertilized eggs undergo a form of parthenogenesis (called arrhenotoky) whereby they develop into haploid males (this is distinct from most other cases of parthenogenesis where females are exclusively produced). Under experimental conditions, the whole life-cycle was completed in as little as 6 days, and female mites were found to live for 9-10 days. Gravid females were found more frequently in the air sacs, syrinx and trachea of the host, while non-gravid non-gorged females were commonly found in the upper respiratory system, particularly the buccal and nasal cavities. It is therefore thought that transmission occurs by the direct transfer of non-gravid non-gorged females to birds in close proximity (via billing behaviour, or parents feeding young). Indeed, these stages are often encountered on the head plumage, bill and nares of infested birds. It is also possible that some indirect transmission may occur via water, perches or other surfaces contaminated by birds coughing or sneezing. The transmission stages have been observed to survive off-hosts for at least 8 hours, but rarely more than 20 hours, and they have been observed to migrate towards heat sources. The transfer of non-gravid females also explains the unusual dynamics observed in the establishment of new infestations. The non-gravid females produced unfertilized eggs giving rise to parthenogenetic haploid males (thus accounting for the large male bias observed in initial infections) whereas subsequent progeny from mated females producing fertilized eggs were diploid females (thus accounting for the large female bias observed in established infections).

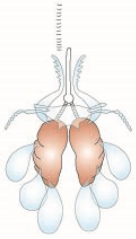
Differential diagnosis: Infestations are rarely diagnosed on the basis of symptomatology, as many other aetiological agents may cause similar signs of respiratory disease (dyspnoea and congestion). Ante-mortem diagnosis is generally afforded by the direct demonstration of mites in the upper respiratory tract, usually by otoscopic examination of the nasal mucosa or endoscopy of the trachea. Transillumination of the trachea of infested birds (using a bright light in a darkened room after moistening the neck) has also been used occasionally to reveal dark specks moving in the lumen. Medical imaging technologies may assist in localizing infestations, with radiography revealing radio-opacities in the pulmonary and air-sac fields. Specimens of mites may sometimes be detected in oral or nasal swabs or lavages, and occasionally in faecal samples. Molecular biological techniques have been used to characterize species and infer phylogenetic relationships following polymerase chain reaction (PCR) amplification of nuclear (5.8S ribosomal RNA, internal transcribed spacers 1 and 2) and mitochondrial (16S ribosomal RNA) gene sequences.

Treatment and control: Clinical infestations should be treated promptly as they may worsen rapidly leading to airway blockages with significant morbidity and mortality. Chemotherapy with acaricides is generally the only option, but care should be exercised as an aggressive course may kill too many mites at once leading to further obstructions and too little medication may not resolve the condition. Treatments should be administered quickly with minimal handling in warm comfortable surroundings, and recovering birds should be rested with easy access to water and food. Supportive care may be required during treatment in the form of anti-inflammatories, decongestants and possibly antibiotics in the case of secondary infections. Good success has been reported in the control and elimination of infestations using macrocyclic lactones (ivermectin or moxidectin) repeated after 2 weeks. It is recommended that all birds in contact be treated at the same time and that attention be paid to any contra-indications to avoid toxicity or residual issues. Preventive measures designed to break transmission cycles should involve animal management (regular health surveillance to inform treatment, quarantine and culling), environmental management (cleaning cages, roosts and nests, spraying residual environmental acaracides (pyrethroids), water disinfection), and wildlife control (excluding wild birds from poultry facilities and aviaries).

Sternostoma

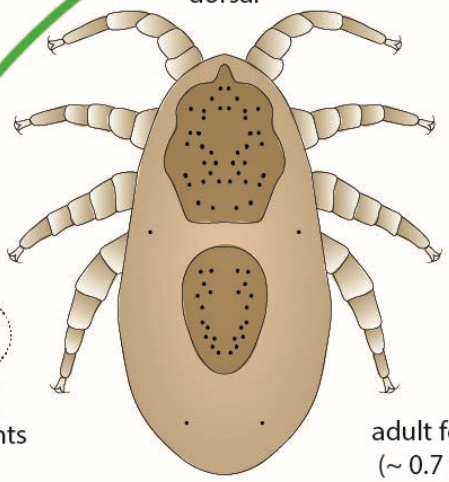
Hosts
(birds)

transmission by transfer of adults during grooming,
allofeeding, courting or via contaminated fomites

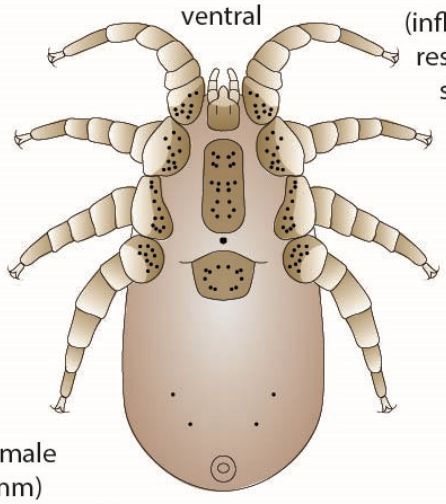


airways
(inflammation,
respiratory
signs)

dorsal



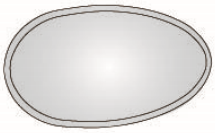
ventral



tarsal
elements

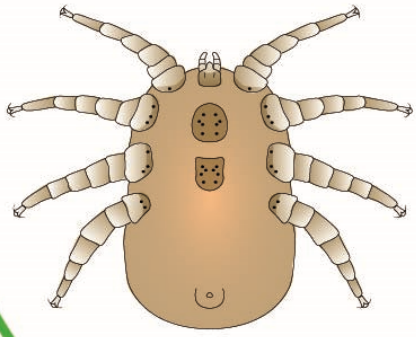
adult female
(~ 0.7 mm)
{some parthenogenetic]

eggs/larvae deposited on epithelia

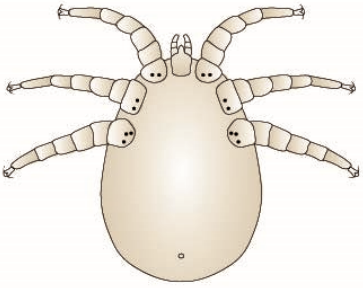


egg
(~ 300 µm)

hatch



nymph
(ventral)
(~ 500 µm)



larva
(ventral)
(~ 400 µm)

larva do not feed

2 nymphal instars
protonymphs (feed),
deutonymphs (do not feed)

protonymphs and adults are 'endoparasitic'
in respiratory passages (feed on blood/lymph)

Sternostoma adult